

Analysing the Diffusion of a Mobile Service Supporting the E-grocery Supply Chain

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Analysing the Diffusion of a Mobile Service Supporting the E-grocery Supply Chain

Abstract

Purpose: The paper proposes a systemic methodology to assess the potential of and facilitate policies for the diffusion of a smartphone based service enabling supply chain (SC) operations in the e-grocery sector.

Design/Methodology/Approach: A System Dynamics (SD) model combining the Bass paradigm for innovation diffusion and an inventory management framework is developed. Semi-structured interviews are conducted to understand the industry business processes; a simple SD model is designed to capture the most important variables together with the relationships among them; a detailed SD model is calibrated and simulation outcomes are analysed.

Findings: The efficiency and reliability of the service drive its diffusion among producers and consumers, who in turn persuade retailers to adopt. The assessment methodology can be part of feasibility studies and marketing investigations in order to understand the impact of e-commerce tools on SC processes.

Research implications: This contribution stresses the need to analyse how mobile information technologies may benefit all the business processes of the e-grocery SC, and not just one single process or stakeholder.

Practical implications: The approach offers a roadmap to identify the factors influencing the diffusion of mobile e-grocery services as well as the associated impacts on SC processes.

Originality/value: The work contributes to overcoming the lack of approaches studying the diffusion of e-grocery by taking into account all the relevant aspects and stakeholders involved and not only the consumer perspective.

Keywords: E-grocery, mobile commerce, ICT services, smartphone applications, supply chain management, information flow, product distribution, innovation diffusion, System Dynamics, Bass model.

1. Introduction

The introduction of micro-browsers and similar applications in wireless communication devices gives the possibility of having the Internet “in one’s pocket” and of performing a variety of activities without being in front of a computer (Barnes, 2002; Lu and Su, 2009).

Merging the Internet and wireless communication technologies brings a new form of electronic commerce, named mobile commerce (m-commerce) (Zeng *et al.*, 2003). M-commerce may be generally defined as all those electronic transactions, such as communication, interaction, purchase, and payment that use wireless device connections to the Internet or to the private network of a vendor (Barnes, 2002; Kauffman and Techatassanasoontorn, 2005).

Despite the current increasing interest of mobile telecommunication providers in offering mobile data services (Al-Debei *et al.*, 2013), M-commerce is in an initial stage of development. Nevertheless, it has tremendous potential. In particular, mobile devices such as smartphones connected to the Internet can purposefully support supply chain management (SCM), from placing orders to delivering products, as well as making the

associated decisions. This is of great value to the logistics industry because the strategic use of wireless and Internet technologies may drive business innovations, increase customer service level, and eventually secure competitive advantage and long term profits (Chen *et al.*, 2009; Hazen and Byrd, 2012).

One promising area of m-commerce is electronic grocery (e-grocery), namely ordering groceries from home in an electronic way and having them delivered at one's house (Verhoef and Langerak, 2001). E-grocery is more convenient and timesaving than the traditional grocery channels because consumers do not have to leave their home to buy products and can do that at any time of the day. In addition online shopping offers accessibility to a wider range of products and stores than buying groceries in supermarkets (Ramus and Nielsen, 2005).

However, the e-grocery market finds it hard to expand. First, selecting items, especially the perishable ones such as fruit, vegetables, meat or seafood, without checking their properties directly causes the risk that the product quality is different from expected (Raijas, 2002). Second, there is a lack of an appropriate control on the information flow and of physical logistics connected to delivery (Punakivi and Saranen, 2001). Also, the typical risks of e-commerce (Wat *et al.*, 2005), such as difficulties in making complaints about products, slow web connections, scarce security of the payment system, and incomplete information about the orders, are among the main reasons why very few customers currently use their mobile phones for purchasing groceries and several e-grocers had to exit the market in the last few years (Lim *et al.*, 2009).

Therefore, in order to provide final consumers with a valuable alternative option to grocery stores, the e-grocery business needs to improve purchase transactions and the physical distribution process, to use electronic/mobile communications for more than

simply placing orders, and to re-engineer the logistics process by connecting all supply chain (SC) members with real time information.

However, research on e-grocery and m-commerce is still in its infancy (Lu and Su, 2009; Ramus and Nielsen, 2005) and, while there is a well-established stream of literature focusing on the advantages and disadvantages of buying groceries online from the consumer point of view, there is a lack of approaches aiming to analyse the diffusion of new SC models and enabling tools by taking into account all the relevant aspects and stakeholders involved. In particular, very few works are aimed at understanding how such models could impact the processes of Business-to-Business (B2B) partners of the SC, such as producers and retailers.

With the purpose of contributing to close this research gap, the present work provides a methodology to assess the potential of and facilitate policies for the diffusion of a novel service for the e-grocery SC relying on mobile phone technology. To this end, a systemic approach is developed based on the integration of the Bass diffusion model with the System Dynamics (SD) methodology. The perspectives of producers, retailers, customers, and the service management company are considered and the associated enabling factors are investigated.

The paper is organised as follows. A review of the relevant literature is presented in Section 2, while Section 3 details the research methodology. The model is described in Section 4 and simulation results and sensitivity analysis are discussed in Section 5. Section 6 highlights implications, limitations, and future research directions.

2. Pertinent Literature

Some relevant research streams are useful to frame the work into existing literature, namely: e-commerce and m-commerce, e-grocery, distribution of online food retailers,

models for studying the diffusion of innovations with particular regard to the Information and Communication Technology (ICT) area, and SD applications to the diffusion trends and SC issues.

2.1 E-commerce, m-commerce, E-grocery, and Distribution of Online Food Retailers

A first stream of studies is concerned with online commerce and e-grocery. There exists quite an extensive body of literature about the advantages that e-commerce brings to business processes and in particular SC ones. E-commerce enables business development to ensure flexibility and prompt market response in an increasing competitive environment (Aldin *et al.*, 2004). This is of particular interest to small and medium enterprises (SMEs) that are required to be flexible, adaptive, and innovative organizations (Subba Rao *et al.*, 2003). However, e-commerce is not widely diffused among SMEs because of a number of barriers, the most important difficulty being to integrate processes of different companies. Integration is a key point in e-commerce because the ultimate goal of this business practice is promoting an end-to-end SC visibility (Cassivi *et al.*, 2005). Given this objective, e-commerce may also be an effective strategy to improve buyer-supplier relationships. On the one hand, sellers are able to offer their products and services to a larger number of customers than with traditional commercial channels. Also, they can have a more direct and improved communication with buyers which makes it possible to supply a better product and to reduce inventory levels along the SC. On the other hand, buyers can choose among a wider range of product options enabling them to easily find the best valued product at the best price (McIvor *et al.*, 2000; Murtaza *et al.*, 2004). Finally, a number of authors have discussed the operational benefits of e-commerce. In particular, the order, delivery, inventory management, and payment processes can be speeded up, thus reducing

operating and inventory costs while increasing customer service (McIvor *et al.*, 2000; Salo, 2007; Tarofder *et al.*, 2013). In addition, e-commerce may lead to reductions in search and switching costs and to significant economies of scale and scope (Murtaza *et al.*, 2004).

Also M-commerce is gradually gaining the attention of both researchers and practitioners. On the one hand, contributions focus on the factors influencing purchase intentions such as the ability to use mobile communication devices, the easiness of access, the usefulness and enjoyment in using m-commerce services, the reliability of the service, and the price/quality ratio (Lu and Su, 2009; Vrechopoulos *et al.*, 2002). On the other hand, digital mobile devices, key telecommunication technologies and players are studied as a foundation to understand the diffusion of m-commerce (Barnes, 2002; Kauffman and Techatassanasoontorn, 2005).

M-commerce is one of the latest ways to implement e-grocery. A lot of works have discussed selling groceries online, mainly from the final consumer's point of view (Corbett, 2001; Morganosky and Cude, 2000). Convenience and social aspects of shopping, range of available products and associated information, price, quality, the performance of supporting technical systems, and the influence of "word of mouth" are the most common beliefs of consumers about e-grocery shopping (Lim *et al.*, 2004; 2009; Ramus and Nielsen, 2005). Additionally, there is a set of motivational factors that drive decisions not only to start, but also to stop, buying groceries online: stopping working, changing jobs, changing working hours, moving, etc. (Hand *et al.*, 2009). Some authors have studied e-grocery from the perspective of five common characteristics that impact the rate of adoption of an innovation: perceived relative advantage, perceived compatibility, perceived complexity, perceived communicability,

and perceived possibility of trying an innovation without huge investments (Hansen, 2005; Verhoef and Langerak, 2001). A number of works have also focused on the structures, costs, and service levels of the distribution processes of companies selling online food in general, and e-groceries in particular, (De Koster, 2002; Kämäräinen and Punakivi, 2004; Punakivi and Saranen, 2001; Yrjölä, 2001) as well as on the associated inventory costs (Lee *et al.*, 2011).

2.2 Analysis of Innovation Diffusion

A second stream of pertinent literature focuses on the trends of innovation growth. With this regard, the S-shaped pattern is one of the most frequently used ways of describing the spread of innovations. At the beginning, a limited number of users, named “innovators”, adopt and form that critical mass that will play a key role in the subsequent diffusion process. Then, other users, defined as “imitators”, will adopt as a consequence of the social interaction with the innovators and of external factors such as advertising. The demand for the innovation first increases and meets its maximum value and then it decreases and equals zero when the market saturation point has been reached. As a consequence, the curve of the cumulated number of adopters grows rapidly when the demand for innovation is rising and then increases at a slower rate while approaching market saturation (Cronrath and Zock, 2007; Michalakelis *et al.*, 2008b; Wu and Chu, 2010). There are numerous models to forecast innovation diffusion in the literature: among others, some of the most popular ones are the Gompertz, Logistic, Bass, and Fisher-Pry models (Fisher and Pry, 1971; Meade and Islam, 2001). In particular, the Bass model (Bass, 1969) has been used in very heterogeneous fields such as retail services, industrial technology, agriculture, education, pharmaceuticals, and consumer durable goods sectors, because it is quite intuitive and simple but, at the same

time, it has a high power of demand forecasting (Daim and Suntharasaj, 2009). The Bass model has been extensively applied in the ICT arena too. Its original formulation and subsequent extended versions are suitable to model the timing of the process of the adoption of a technology, tightly dependent on the innovation attitude of each class of potential adopter (Liu and Forsythe, 2011). The Bass model has been implemented to study the diffusion of mobile telephony and communication infrastructures such as, for instance, broadband in single national contexts (Chu *et al.*, 2009; Michalakelis *et al.*, 2008b; Turk and Trkman, 2012; Wu and Chu, 2010). In addition, it has been applied to forecast the demand of mobile communication services (Shin *et al.*, 2007). With the aim of capturing the complex cause and effect relationships among the factors involved in the diffusion of an innovation in the ICT field, some contributions rely on the SD representation of the Bass model provided by Sterman (2000) to develop frameworks for identifying the economic and socio-cultural determinants affecting the capacity to adopt ICT innovations, defining policies to stimulate the diffusion of ICT solutions, or forecasting the success of products either prior to their launch or during their lifecycle (Cronrath and Zock, 2007; Dahan, 2011).

2.3 System Dynamics Modelling of Supply Chains

A third stream of pertinent literature is associated with the application of SD to SCs. Since the approach developed in this work is intended to assess a service supporting SC operations, it has to be able to link the diffusion pattern to the SC structure associated with inventory, orders, and deliveries. SD proves to be useful for this purpose. SD is a modelling and simulation approach aimed at understanding the behaviour of a complex system to support policy design. This methodology enables us to graphically represent a system of interrelated stock, flow, and auxiliary variables, define the mathematical

equations describing the relationships among them, and perform a computer-based simulation to determine the trends of the investigated variables over a preset period of time. Model validation is performed through historical data and sensitivity analysis (Forrester, 1961; Sterman, 2000).

Sterman (2000) offers a very detailed SD representation of a SC. Based on his work, contributions focus on several issues affecting both manufacturing and service industries (Anderson and Morrice, 2000; Ashayeri and Lemmes, 2006; Panov and Shiryaev, 2003). SD has been applied to capture the interrelation between SC responsiveness and efficiency and to study the effects of strategies to improve them (Minnich and Maier, 2006). Responsiveness to demand variability has also been tackled by Gonçalves and others (2005) with the purpose of showing the effects of product availability on customer demand and proving the reinforcing feedback between demand fluctuation and the consequent adjustment of the production capacity. Furthermore, SD models have been developed to examine instabilities in SC due to actions addressing the imbalances between supply and demand like price changes, promotions, and the involvement of additional suppliers (An and Ramachandran, 2005). SD proved to be beneficial in SC reengineering and to characterise the conditions under which the bullwhip effect can occur (Anderson Jr. *et al.*, 2005; Croson and Donohue, 2005). Finally, SD models have been extensively used to evaluate the operational and economic performance of SCs (Cagliano *et al.*, 2011; De Marco *et al.*, 2012; Venkateswaran *et al.*, 2011).

Based on the literature review, it can be stated that research on the e-grocery SC has mainly focused on the viewpoint of a single echelon, namely the final consumer, and

that scarce attention has been given to the simultaneous consideration of all the SC partners and to the extent to which they relate to each other. B2B partners such as producers and retailers should be considered as well because it has been proven that e-commerce technologies show their greatest application potential with such transactions (McIvor *et al.*, 2000). Also, numerous works addressing the factors enabling the diffusion of e-grocery and mobile services supporting product distribution are survey-based ex-post studies (Corbett, 2001; Hand *et al.*, 2009; Morganosky and Cude, 2000) and there is a substantial lack of frameworks to assist companies in preliminary assessment of the feasibility of promoting m-commerce services for the grocery SC as well as their impacts on business processes. Finally, looking at the literature about the SD methodology, many current applications are focused on either the innovation diffusion paradigm or the SC structure separately without specifically addressing how the diffusion mechanisms may affect or be affected by SC operations.

The present work seeks to contribute to overcome these research gaps through the proposal of a managerial approach to analyse the operational and economic impacts of the diffusion of a service supporting the e-grocery SC based on mobile phone technology. The Bass diffusion model and an inventory management model have been combined in a single SD framework in order to capture the mutual connections between the adoption of the service and the SC behaviour. All the three main echelons, namely producers, retailers, and consumers, are considered with the aim of offering a decision-making tool allowing a systemic ex-ante evaluation of the potential of new technology-driven SC services as well as the testing of associated business policies.

3. Service Description and Research Methodology

The service addressed by this work relies on a web application for smartphones that enables online order placement, inventory control, dispatching and receiving management. All users share product, order, inventory, and shipment information and are charged a fee for receiving orders or dispatching deliveries through the online service. Figure 1 depicts the block diagram of the software architecture of the mobile service. The smartphone application is the interface that connects users to a central server and has two main functionalities, namely supporting vehicle routes and assisting SC operations. In the central server, a Data Aggregator receives information about traffic conditions from external sources and about deliveries from the Supply Chain Management Unit to provide the Traffic Handler Service with data to generate travel distances and times and other inputs for the Routing Optimiser. The intelligent real-time vehicle routing system (Deflorio *et al.*, 2012; Perboli *et al.*, 2008) builds optimised routes for the efficient transportation of freight. The Service Information Management Unit sends such routes to the user's smartphone application as well as to the Supply Chain Management Unit of the server. This part of the service architecture receives orders from users and sends them to the associated suppliers, manages information and tools for delivery planning and execution, allows electronic monetary transactions, updates inventory levels, and collects statistics about orders, deliveries, and stocks to support distribution activities. The outcome of the Supply Chain Management Unit is also stored in the Data Aggregator to serve as past data for the routing task.

Take in Figure 1 about here

The reference market is composed of producers, retailers, and consumers of fresh food in a target urban area in Italy with a 1.5 million population.

With the aim of understanding the diffusion of the new mobile service for the e-grocery SC within the community of prospective adopters and assessing the potential business for the service management company, Telecom Italia, a phased approach is used (Lyneis, 1999). First, semi-structured interviews are conducted with local consumers, retailers, and producers to create a knowledge base on the industry processes. The interviews also identify a clear willingness of the SC players to adopt the service and provide quantitative data for running simulations. Then, a simple SD model is designed to capture the most important flows, state variables, and feedback loops. Finally, a detailed SD model is calibrated and simulation results are analysed to draw implications supporting the decisions of whether and how to develop such a mobile service. The Bass model has been used given its recognised ability to represent the dynamics of diffusion of ICT-based and mobile services.

4. The System Dynamics Model

The SD model is structured into six interconnected sub-models concerned with the diffusion of the service among consumers, retailers, and producers, order issuing, inventory management, user satisfaction, and the revenue for Telecom Italia (Figure 2). The six sub-models are mainly inspired by previous SD representations of the Bass diffusion and manufacturing SC models as proposed by Sterman (2000). Such models are a main source of primary foundation of any model willing to replicate the mechanisms of technology diffusion within the patterns and dynamics of a complex supply chain. The studied SC includes those actors relying on the mobile service for both placing orders upstream and delivering goods downstream.

The model has been developed using the Vensim® DSS software package. The simulations have been performed with Euler integration, with one-day time intervals and a simulation horizon of 156 weeks corresponding to about 3 years.

Take in Figure 2 about here

The structure of the SD model is characterised by many feedback loops explaining the interaction between the diffusion of the new service and the SC operations. A growth in the number of consumers adopting the mobile service increases their order rate to retailers and how successful these actors are in fulfilling the augmented orders determines the consumer satisfaction that, in turn, influences the growth of adoption in the consumer population through the “word of mouth” effect. A similar situation can be observed for retailers and producers. Also, all the other variables remaining equal, a growing number of orders to the producers make the order rate to each single producer go up. The possibility of increasing the business volume with the new service is perceived by the retailers that are stimulated to adopt. Finally, the more producers that adopt, the more the products are available for retailers, and the higher the retailer satisfaction. This, in turn, increases the number of adopting producers thanks to the interaction between these two SC echelons.

Each SD sub-model is discussed in the following sections. The list of the equations is available in the Appendix.

4.1 “Consumer Diffusion and Orders” Sub-model

Figure 3 shows the dynamics governing the adoption of the mobile SC service by consumers. This sub-model is based on previous SD representations of the Bass diffusion model developed by Ben Maalla and Kunsch (2008), Dahan (2011), Sterman (2000), Thun and others (2000), and Yücel and van Daalen (2009).

The stock of “Potential Consumers” is decreased by the “Consumer Service Adoption Rate”, which in turn increases the stock of “Consumers”. Consumers may adopt, thus entering the SC of the service users, as a consequence of either advertising or “word of mouth”. In this model, advertising is performed by both the suppliers that have already adopted the mobile service, through verbal persuasion to use it because of its efficiency and ease of use, and Telecom Italia, by means of formal campaigns, whereas “word of mouth” is pursued by adopting customers and members of a same SC echelon. Therefore, the developed application of the Bass model considers the co-influence of different SC partners in the diffusion process (Michalakelis *et al.*, 2008a).

The number of adopting consumers, together with the average number of orders per consumer in each single time step, determines the “Consumer Order Rate” which feeds the stock “Consumer Orders”. The present SD model is based on a standard order composition and does not consider the variability of the products that form an order.

Take in Figure 3 about here

4.2 “Retailer Diffusion” Sub-model

The dynamics of the diffusion of the mobile SC service among retailers is similar to the diffusion among consumers (Ben Maalla and Kunsch, 2008; Dahan, 2011; Sterman, 2000; Thun *et al.*, 2000, and Yücel and van Daalen, 2009) (Figure 4). In particular, the more orders placed by retailers to producers, the more producers will be encouraged to propose new retailers to enter the community of users. Also, the consumers that are satisfied with the new service will stimulate retailers to adopt it so that they can experience the purchase of products supported by the mobile service from a larger number of suppliers. In addition, the retailers measure their satisfaction and make their service-entrance decision based on the level of service and business volume reached by

their adopting competitors. This emulation is a particular kind of “word of mouth”, though not explicit like the one carried out by consumers.

Take in Figure 4 about here

4.3 “Retailer Inventory and Consumer Satisfaction” Sub-model

This part of the SD model represents the inventory performance of retailers that use the mobile service as well as the consumer satisfaction (Figure 5).

The portion of the sub-model about the retailer inventory is based on previous modelling developed by An and Ramachandran (2005), Georgiadis and others (2005), Handel (2014), Huang and Wang (2007), and Sterman (2000). The unit of material in the studied SC is the order. The stock variable “Single Retailer Inventory” is augmented by the flow of orders received from producers by each single retailer (“Single Retailer Receiving Rate”) and diminished by the flow of orders shipped to consumers (“Single Retailer Shipment Rate”). The consumer demand determines both the shipment rate, according to the number of orders available on stock, and the orders to the producers based on a forecast of future consumer orders modelled as a first-order exponential smoothing of the present order rate.

The part of the sub-model concerned with consumer satisfaction is an original contribution and little of the models available in the literature have been used. Two components have been assumed to be relevant to consumer satisfaction: the service level and the sensitiveness to the price of the service (Zeithaml *et al.*, 1993). The variable “Consumer Receiving Service Level” assesses the service level perceived by the consumers that place orders and receive goods via the mobile service. It is defined as the product of “Consumer Order Fulfilment Ratio”, which measures how many orders are fulfilled in every time step, “E-Order Service Reliability”, which assesses the

degree of reliability and security of the electronic system to place orders, and “Consumer Receiving Timeliness and Efficiency”, which evaluates the efficiency of receiving goods with the support of the mobile SC service. The variable “Consumer Sensitiveness to Pricing” compares the price expected by consumers with the actual one. In addition to the “Receiving Unit Fee”, which is paid by users that place and receive an order supported by the mobile service, and the “Dispatching Unit Fee”, paid by users when they deliver an order with the aid of the service, each SC member is also charged with the “WebApp Unit Price” in order to download the software application allowing interaction with the mobile service. “Receiving Unit Fee”, “Dispatching Unit Fee”, and “WebApp Unit Price” do not depend on the SC member using the service, being a producer, a retailer or a consumer. To be more precise, “Consumer Sensitiveness to Pricing” is defined as per Equation (1):

$$\text{Consumer Sensitiveness to Pricing} = \frac{\left(\frac{\text{Expected Receiving Unit Fee}}{\text{Receiving Unit Fee}} \right) + \left(\frac{\text{Expected Web App Unit Price}}{\text{WebApp Unit Price}} \right)}{\text{Max Consumer Sensitiveness to Pricing}} \quad (1)$$

where “Max Consumer Sensitiveness to Pricing” compares the maximum expected values of the service fees with their minimum actual values.

“Consumer Satisfaction” is then calculated as per Equation (2):

$$\text{Consumer Satisfaction} = \text{Consumer Receiving Service Level} * (1 - \text{Weight of Pricing}) + \text{Consumer Sensitiveness to Pricing} * \text{Weight of Pricing} \quad (2)$$

where “Weight of Pricing” represents the importance of the price of the service in determining the user satisfaction. It is assumed to be the same for all the SC echelons.

Take in Figure 5 about here

4.4 “Producer Diffusion” Sub-model

The sub-model describing the diffusion of the mobile service among producers is very similar to the ones explaining the dynamics of service adoption by consumers and retailers (Figure 6). As above, this section of the model uses equations and relationships developed by Ben Maalla and Kunsch (2008), Dahan (2011), Sterman (2000), Thun and others (2000), and Yücel and van Daalen (2009).

Take in Figure 6 about here

4.5 “Producer Inventory, Retailer Satisfaction, and Producer Satisfaction” Sub-model

The present sub-model deals with the inventory dynamics of producers using the mobile service and assesses retailer and producer satisfactions (Figure 7a and Figure 7b).

Similarly to the retailer inventory, the portion of the sub-model about the producer inventory is based on the contributions by An and Ramachandran (2005), Georgiadis and others (2005), Handel (2014), Huang and Wang (2007), and Sterman (2000).

. Both retailer and producer satisfactions are assessed in the same way as the consumer satisfaction. In particular, “Retailer Service Level” is defined as the sum of “Retailer Receiving Service Level” and “Retailer Dispatching Service Level” because a retailer may use the mobile service to both receive and dispatch orders. “Retailer Receiving Service Level” is given by an equation that is very similar to the one defining the variable “Consumer Receiving Service Level” (Section 4.3). “Retailer Dispatching Service Level” is determined as the product of “E-Order Service Reliability”, assessing the reliability and security of the electronic system to receive orders from consumers, and “Info Routing Reliability”, evaluating the reliability of the real-time vehicle routing system supporting product dispatching. Thus, the retailer satisfaction is calculated as per Equation (3):

$$\begin{aligned} \text{Retailer Satisfaction} &= \text{Retailer Service Level} * (1 - \text{Weight of Pricing}) + \\ &+ \text{Retailer Sensitiveness to Pricing} * \text{Weight of Pricing} \end{aligned} \quad (3)$$

where “Retailer Sensitiveness to Pricing” is calculated similarly to “Consumer Sensitiveness to Pricing”.

The producer’s satisfaction is computed through equation (4):

$$\begin{aligned} \text{Producer Satisfaction} &= \text{Producer Dispatching Service Level} * (1 - \text{Weight of Pricing}) + \\ &+ \text{Producer Sensitiveness to Pricing} * \text{Weight of Pricing} \end{aligned} \quad (4)$$

where “Producer Dispatching Service Level” and “Producer Sensitiveness to Pricing” are defined similarly to “Retailer Dispatching Service Level” and “Consumer Sensitiveness to Pricing” respectively. It is worth highlighting that a producer may use the mobile service just for dispatching orders and not also for placing orders with her suppliers.

Take in Figure 7a about here

Take in Figure 7b about here

4.6 “Revenue Growth” Sub-model

The revenue growth sub-model evaluates the revenue for Telecom Italia produced by the diffusion of the mobile service (Figure 8). The revenue is a quantity that has been already used to study the economic benefits for mobile phone operators offering value added services such as data transmission and internet connection (Nejad Amiri and Kian, 2008).

The SD model calculates the total cumulative revenue (“Total Revenue”) as the sum of the revenue from supporting the activities of receiving and dispatching orders (“Subtotal Revenue”) and the revenue from selling the software packages to connect the users’ smartphones with the mobile service, as per equation (5)

$$\text{Total Revenue} = \text{Subtotal Revenue} + \text{WebApp Unit Price} * (\text{Consumers} + \text{Producers} + \text{Retailers}) \quad (5)$$

The variable “Subtotal Revenue” is in turn defined as the cumulative value of the revenues from order receiving and dispatching activities supported by the mobile service:

$$\text{Subtotal Revenue} = \text{INTEGRAL} (\text{Revenue Rate from Consumer Receiving} + \text{Revenue Rate from Retailers} + \text{Revenue Rate from Producer Dispatching}) \quad (6)$$

where “Revenue Rate from Retailers” is obtained by adding the revenue rate from the retailer order receiving activities (“Revenue Rate from Retailer Receiving”) and the revenue rate from the retailer dispatching activities (“Revenue Rate from Retailer Dispatching”).

The variables “Revenue Rate from Consumer Receiving”, “Revenue Rate from Retailer Receiving”, “Revenue Rate from Retailer Dispatching”, and “Revenue Rate from Producer Dispatching” are given by multiplying the appropriate shipment rate by either the receiving or the dispatching unit fee.

Take in Figure 8 about here

5. Simulation Results and Sensitivity Analysis

Before running simulations, the model was calibrated with numerical values obtained from a variety of sources, namely: semi-structured interviews with the target SC players, market studies on the urban area at issue, and discussions with experts of the service providing company as well as past data provided by this organisation (Table 1).

Take in Table 1 about here

As far as the interviews are concerned, a panel of twenty producers, twenty retailers, and twenty consumers of fresh food operating in the reference area were selected and

posed questions about their operational processes, business volumes, and purchasing habits. In particular, retailers and producers were asked to provide the number of customers they serve, the number of suppliers they rely on, the number of orders they receive from a same customer per week, and the amount of time it takes to process a single order.

The outcomes of the interviews, supported by local market studies, suggested that in the reference market there are one hundred consumers on average and five local producers per single retailer. These numbers assume that consumers/retailers may buy from more than one retailer/producer. Seven hundred and fifty retailers were identified to operate in the target geographical area that in total serve approximately seventy-five thousand consumers and buy products from about three thousand seven hundred and fifty producers. These values were assumed to adequately describe the consumer, retailer, and producer populations in the SD model.

Retailers were also asked how many orders one consumer places in a week: the average value of the answers that were obtained is one order per week, meaning 0.2 order/time because the time step of the SD model equals one work day and the simulation time horizon is expressed in weeks.

As far as the order processing time is concerned, average retailers take at least one day to fulfil an order, while producers reported a range of values due to the variable size of the orders they receive. Also, the processing time can be quite long because products might not be immediately available to producers. This happens for instance when fruits or vegetables still need to be picked or when the producer buys the ordered items from a supplier. By averaging all the answers the minimum order processing time for producers goes from one to five days. The mean value of three days is used in the SD model.

The rates at which SC players have contacts with each other were set according to previous studies performed by the service providing company in similar SC contexts. The figures of the advertising effectiveness reported in Table 1 were defined based on past data obtained from Telecom Italia's campaigns related to similar mobile services. Conservative values were set in order not to overestimate the effects of advertising. Finally, the values for the variables "Receiving Unit Fee", "Dispatching Unit Fee", and "WebApp Unit Price" were defined together with Telecom Italia based on the pricing policy the company is planning to adopt for the present service.

The base case simulation results in the mobile service being adopted by the total populations of consumers, retailers, and producers in 12.6, 10.2, and 82.3 weeks respectively. The base case also provides evidence of a SC in equilibrium with steady inventory levels.

A sensitivity analysis is then carried out with the purpose of testing the model robustness and supporting policy making.

Figure 9 shows the results of the multivariate sensitivity analysis assessing the dynamics of the service users growth when "E-order Service Reliability", "Consumer Receiving Timeliness and Efficiency", "Retailer Receiving Timeliness and Efficiency", and "Info Routing Service Reliability" change randomly according to a triangular distribution between 0 and 1. The diagrams present the confidence bounds within which the number of consumer, retailer, and producer adopters can be found with a probability of 50%, 75%, 95%, and 100% as the above quantities simultaneously vary. The retailer population growth is relatively insensitive to changes in the efficiency and reliability of the service. In fact, from Figure 9 it can be seen that the confidence bounds are very narrow and close to the line associated with the base case. On the contrary, the

confidence bounds related to both consumer and producer growths are wide, meaning that these two adoption dynamics are largely affected by variability. In particular, the confidence bounds describing the producer growth are significantly different from the base case adoption curve line and are all associated with a much slower diffusion process. Thus, a very long time might be necessary to disseminate the usage of the mobile service among producers. The sensitivity runs show that at the end of the simulation time horizon a limited number of producers have adopted the mobile service out of the entire population of three thousand seven hundred and fifty organisations.

Take in Figure 9 about here

The dynamics of user growth does not appear to be sensitive to the variation of the service fees, even when all the SC players are set to be extremely sensitive to pricing. As an example, Figure 10 illustrates the sensitivity of population growth when the “Dispatching Unit Fee” changes out of a random distribution. As shown by the three diagrams, the confidence bounds associated with the adoption curves of consumers, retailers, and producers are all very narrow and close to the base case lines. Thus, the dynamics of the service diffusion among the three SC players basically does not change with small variations in the fee. Similar results were found for the “Receiving Unit Fee” and the “WebApp Unit Price”. These outcomes might be justified by the fact that efficiency and reliability of professional services are better adoption incentives than low costs.

Take in Figure 10 about here

Additionally, “Telecom Italia-Producer Advertising Effectiveness” is an important parameter for the adoption rate of producers because its variation brings significant changes to their saturation period. Figure 11 shows the outcomes of the sensitivity

analysis on this variable. The confidence bounds of the output variable “Producers” are wider than those of the variables “Consumers” and “Retailers” and the time period when the producer market saturation is reached is different for each bound. On the contrary, the confidence bounds of the output variables “Consumers” and “Retailers” are narrow and close to the base case lines proving that the variable “Telecom Italia-Producer Advertising Effectiveness” has a much lower impact on consumer and retailer growth patterns.

Take in Figure 11 about here

Also, given high values to “Telecom Italia-Producer Advertising Effectiveness”, the community of producers would drive the diffusion across the SC and the saturation time span increases from producers to consumers. In fact, when “Telecom Italia-Producer Advertising Effectiveness” equals 1 the market saturation time periods are 7.4 weeks for producers, 14.6 weeks for retailers, and 15 weeks for consumers.

On the contrary, “Telecom Italia-Consumer Advertising Effectiveness” and “Telecom Italia-Retailer Advertising Effectiveness” have limited influences on the growth of user populations as it can be seen from the narrow confidence bounds associated with the output variables “Consumers”, “Retailers”, and “Producers” when such input variables randomly change (Figures 12 and 13).

Take in Figure 12 about here

Take in Figure 13 about here

Finally, the mutual causal influence of the level of inventory on the population growth is an important aspect to capture the trend of diffusion of the mobile service. The inventory level is determined as a combined effect of the population growth of each SC

echelon as well as its suppliers and its customers. On the one hand, the inventory level is increased by the rate of incoming groceries that depends on the total amount of offered products, which is a function of the number of suppliers, and on the number of SC partners among which such products are divided. On the other hand, the inventory level is decreased by the shipment rate, which is influenced by the order rate received by each single SC player. This is in turn a function of both the number of customers and the number of competitors. Also, the inventory level contributes to the user community growth because it influences both the customer satisfaction, through the shipment rate, and the number of orders placed to suppliers, which is an indicator of the business volume that may stimulate new adoptions.

5.1 Interpretation of Results

Several implications can be drawn from the results of simulations and sensitivity analyses. First, the efficiency and reliability of the mobile service designed for placing and managing orders and for tracking and assisting routing of deliveries prove to be determinant aspects to catalyse and speed up its adoption, especially by producers and consumers. Adopting producers would act to persuade retailers and, at the same time, satisfied consumers would facilitate adoption from “word of mouth” by additional retailers.

Second, the pricing policy turns out to be not influential in addressing the dynamics of service adoption by the SC players because the cost is perceived to be rather cheap for this kind of service and to offer a large potential for economic return from accrued business growth. As a consequence, Telecom Italia can adjust its pricing policy according to the expected dynamics of revenue growth.

Third, advertising efforts are most effective when directed downstream along the SC, from producers to consumers. On the contrary, if the population of consumers is the advertising target, the upward SC contamination would be less effective.

Thus, producers and consumers are the communities that drive the diffusion of the mobile SC service and stimulate from both sides the adoption by retailers. Also, a low level of initial competition between retailers might facilitate business development and revenue growth. In fact, few retailers generate a high order rate per single player, which activates emulation from other retailers to reach a similar business volume. In the meantime, producers and consumers are likely to carry out their action to stimulate adoption by retailers.

6. Discussion and Conclusions

Having appropriate informational and logistics structures govern the SC activities of e-grocery is a priority in the current marketplace (Punakivi and Saranen, 2001). However, their success depends on the availability of frameworks able to prioritize the main contributing factors and stakeholders prior to their implementation. In particular, the benefits for both the users and the companies providing the supporting services should be assessed from a quantitative point of view. In addition, e-grocery is generally recognised as a discontinuous innovation because it implies technological advances and patterns of behaviour completely different from choosing groceries from supermarket shelves, especially when it comes to fresh food (Hansen, 2005; Lim *et al.*, 2009). Also, innovations like e-grocery, usually based on technological architectures made up of multiple modules carrying out different functions, bring strong interconnections among technology, business policies, and economic performance (Koellinger, 2008). Such mutual influences together with the novelty of the e-grocery paradigm add substantial

complexity to organisational systems that are already complex such as SCs (Choi *et al.*, 2001). Thus, a methodological approach relying on tools to capture and deal with complexity is necessary to properly assess the practicality and effects of new products and services on business processes. To that end, the present work builds upon a well-established methodology for studying complex systems and a consolidated model for innovation diffusion to put forward a managerial approach to analyse the pattern of adoption of a mobile service for order, inventory, and delivery management. The impacts of this service on SC processes are also highlighted. From an academic point of view, this contribution stresses the need to go beyond the traditional perspective focused on final consumers and to consider how mobile information technologies may benefit the whole e-grocery SC, including B2B partners, thus stimulating its integration (Cassivi *et al.*, 2005; Subba Rao *et al.*, 2003; Yrjölä, 2001). Additionally, the work suggests that a structured ex-ante evaluation of the actual potential of new e-grocery services can be an important factor in surviving in today's challenging and dynamic business context. Finally, the developed model stimulates the combination and adaptation in the area of SCM of literature-based SD models addressing the topic of innovation diffusion.

From a practitioners' point of view, the proposed approach offers a roadmap to identify the key enabling factors of the diffusion of mobile e-grocery and to simulate their impact overtime. This can purposefully complement feasibility studies and marketing investigations when either introducing new services or upgrading existing ones. Also, it may support decision making about specific business policies. Moreover, such an assessment may facilitate the development process of telecommunication services in order to refine the choice of the enabling technologies before the prototype phase, with

significant savings in terms of investment costs. Additionally, the SC part of the developed SD model may help companies to anticipate the positive and negative effects on business processes of entering the e-grocery market. Finally, the flexibility of the SD methodology enables not only quantitative but also qualitative evaluations according to the availability of information.

Future research can extend the scope of the model to include additional players with different approaches to the use of the service and further factors affecting the expansion of mobile e-grocery. Also, the connection between this work and the concept of smart vehicles for freight distribution (Deflorio *et al.*, 2010; Lee *et al.*, 2011; Stefansson and Lumsden, 2009) might be explored.

In conclusion, the work presents a comprehensive decision-making approach to understand the factors that might influence the dynamics of growth of a mobile service supporting the e-grocery SC. The framework also suggests a methodology for studying the interconnections between the diffusion of e-grocery services and SC processes and can be accommodated to be applied to different services.

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Appendix

See on-line appendix

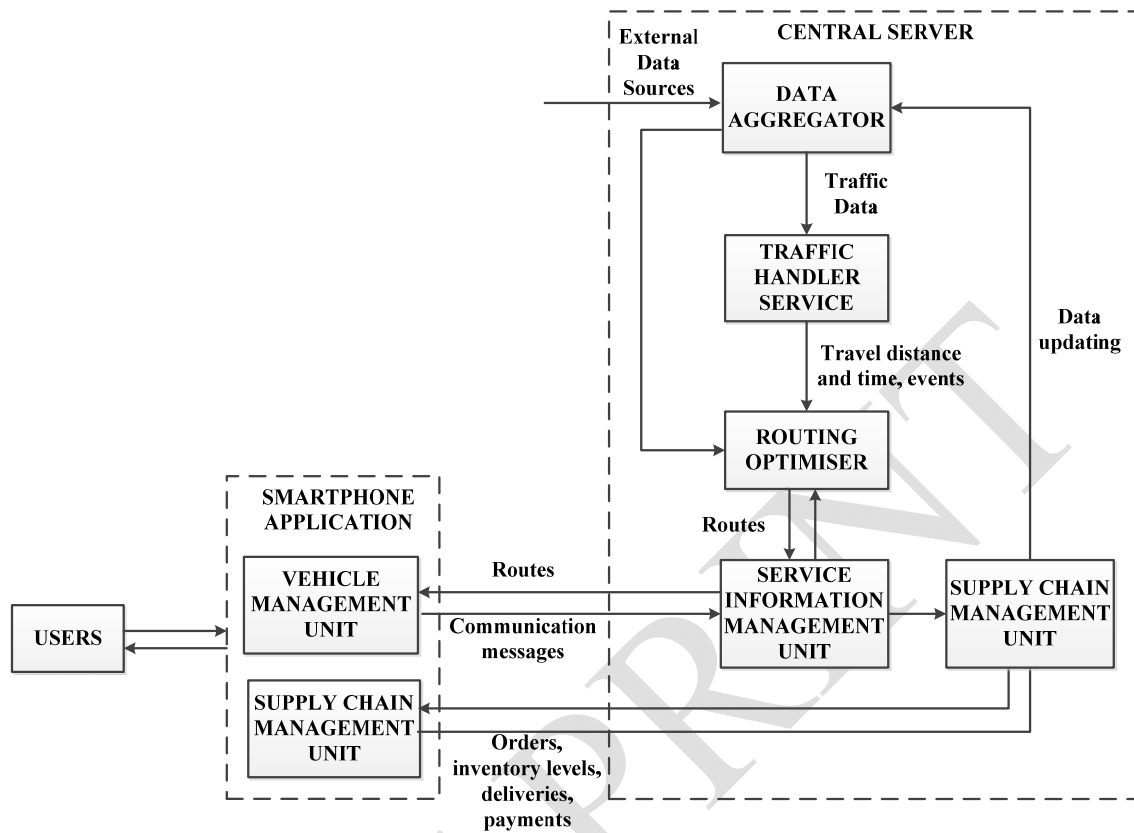


Figure 1. Architecture of the mobile service

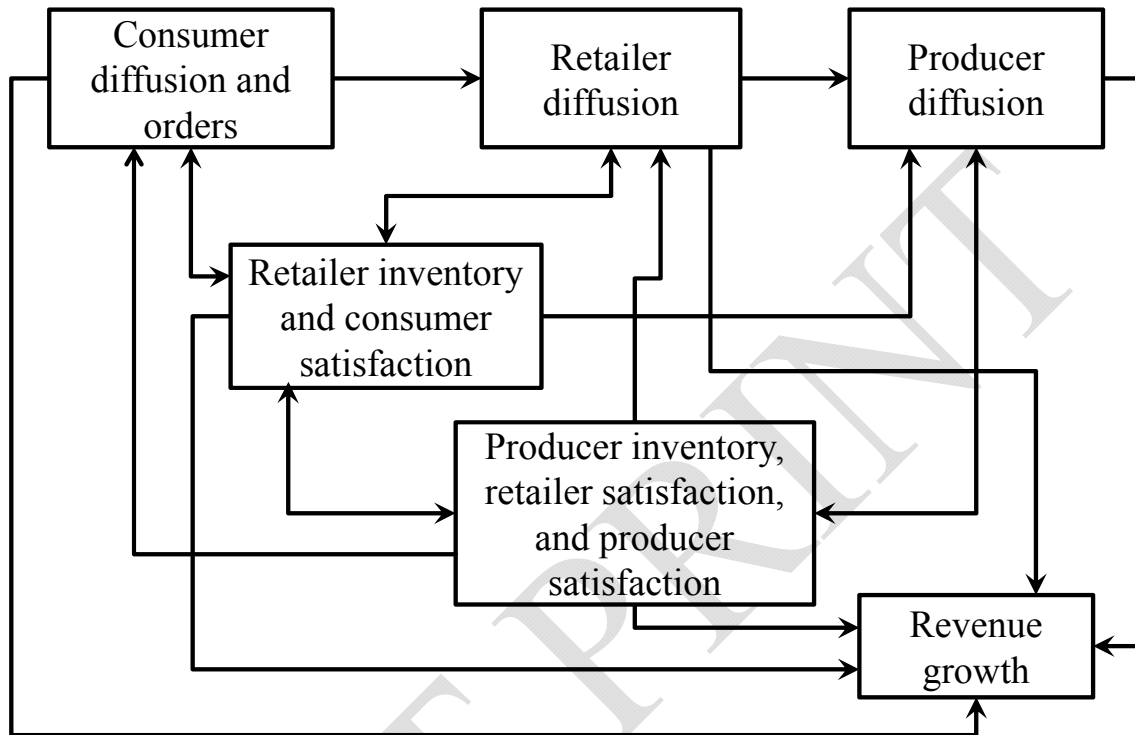


Figure 2. Overview of the SD model

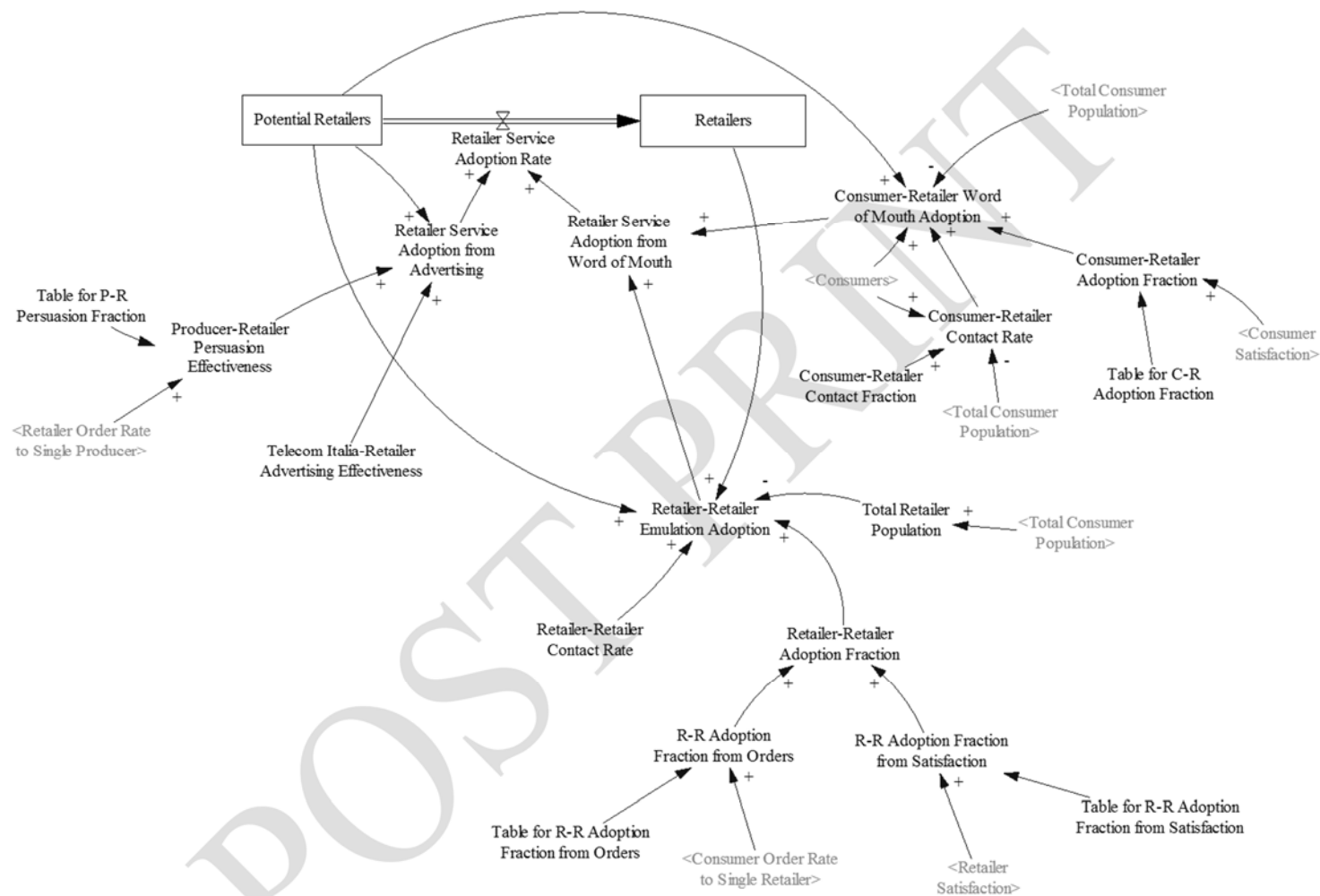


Figure 4. Retailer diffusion

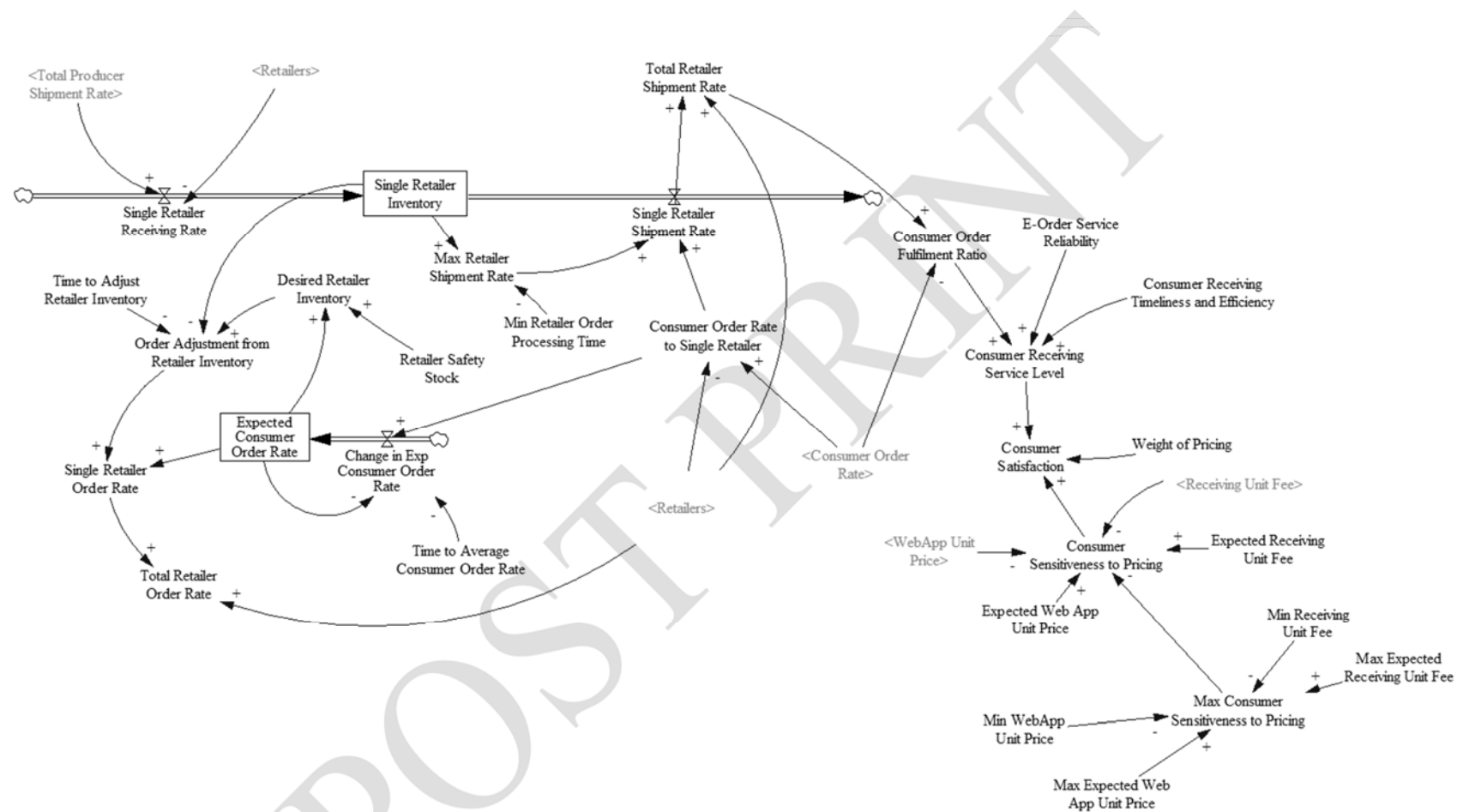


Figure 5. Retailer inventory and consumer satisfaction

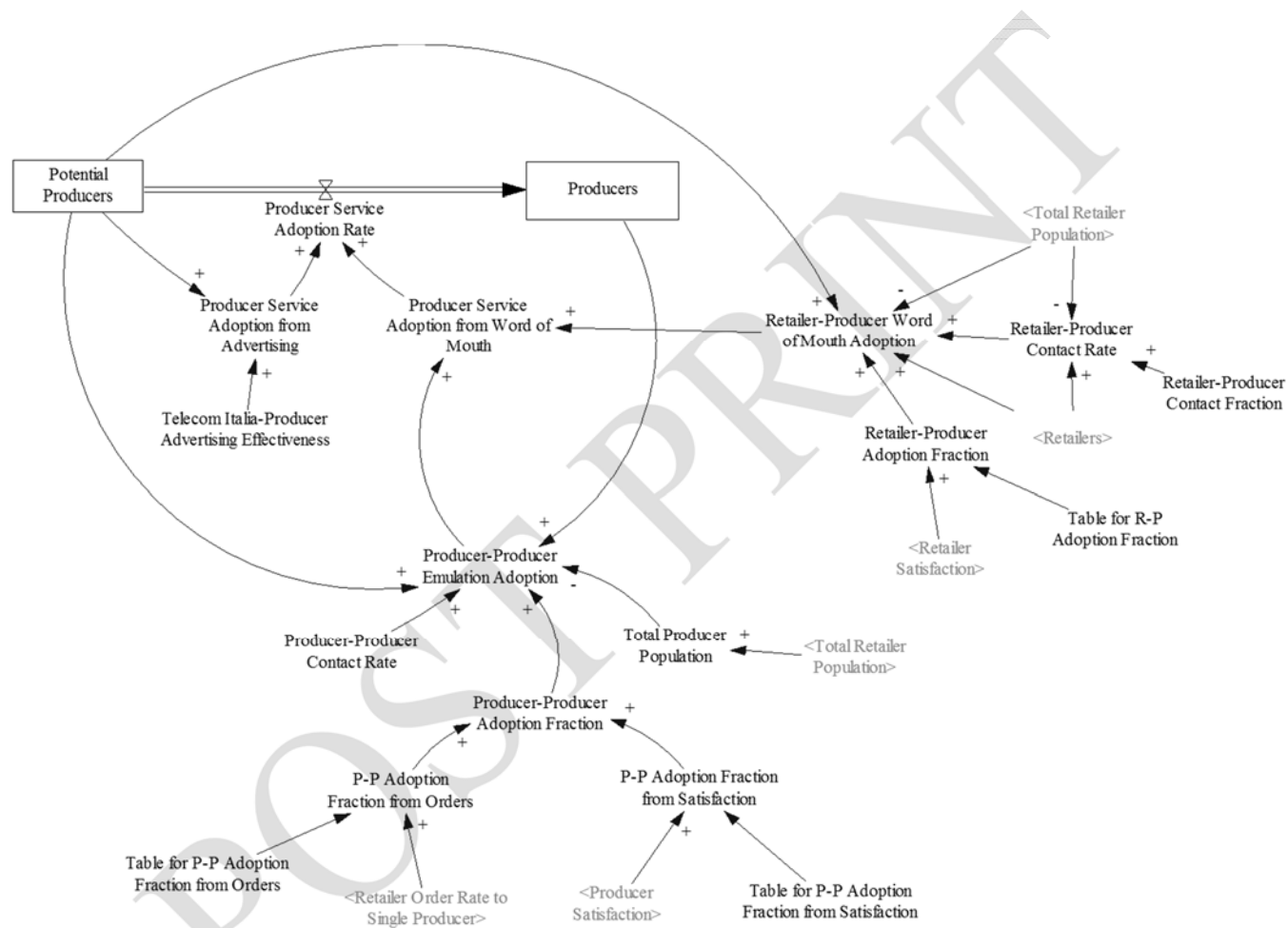


Figure 6. Producer diffusion

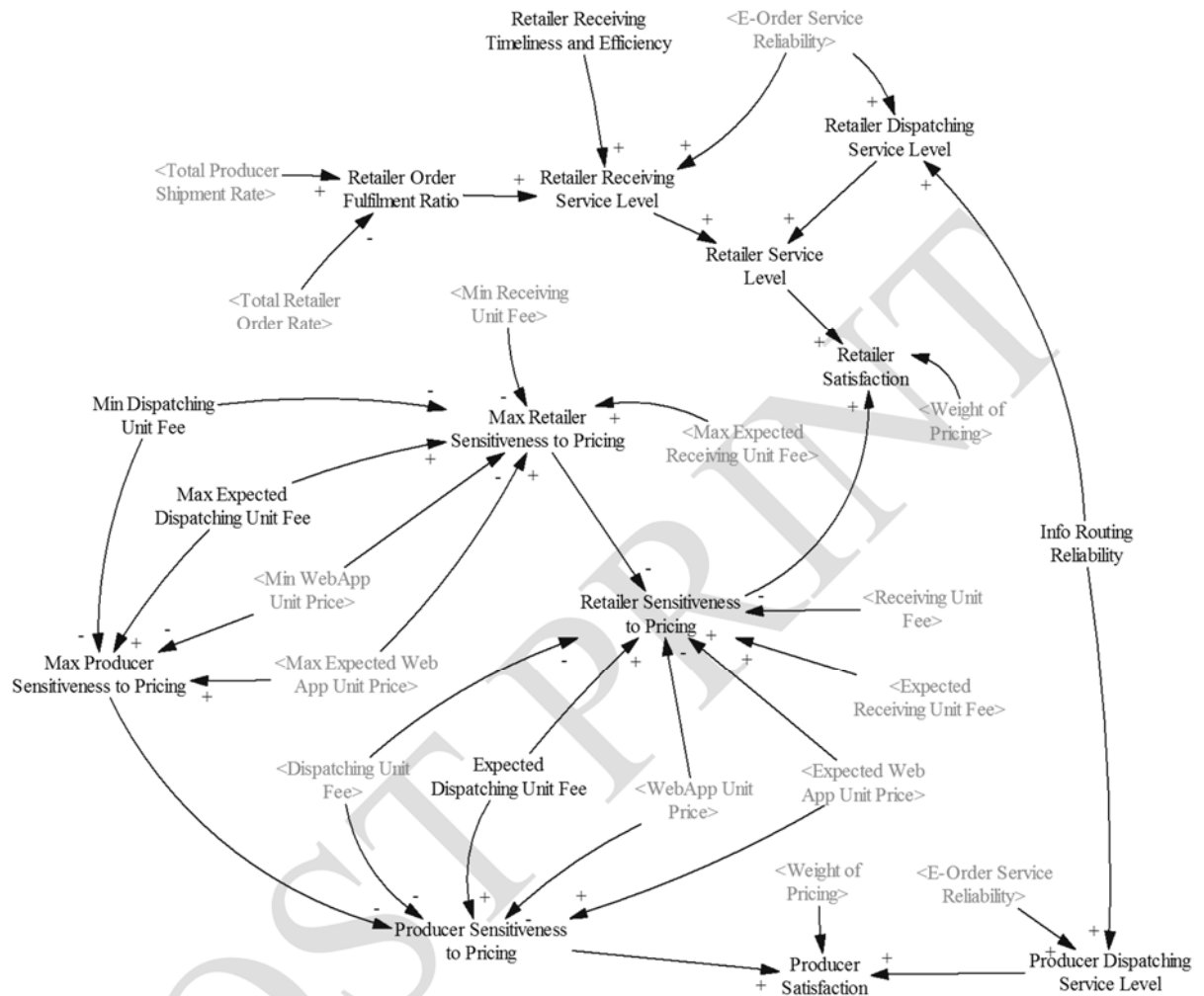


Figure 7b. Retailer and producer satisfactions

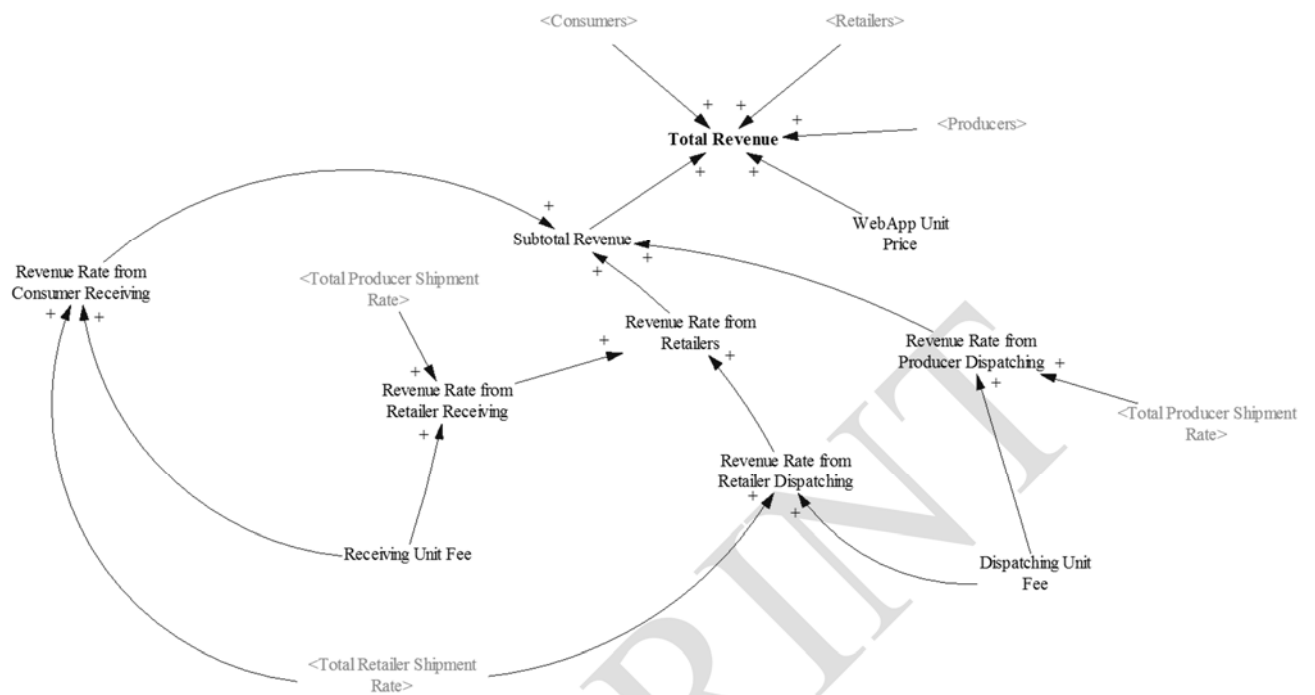


Figure 8. Revenue growth

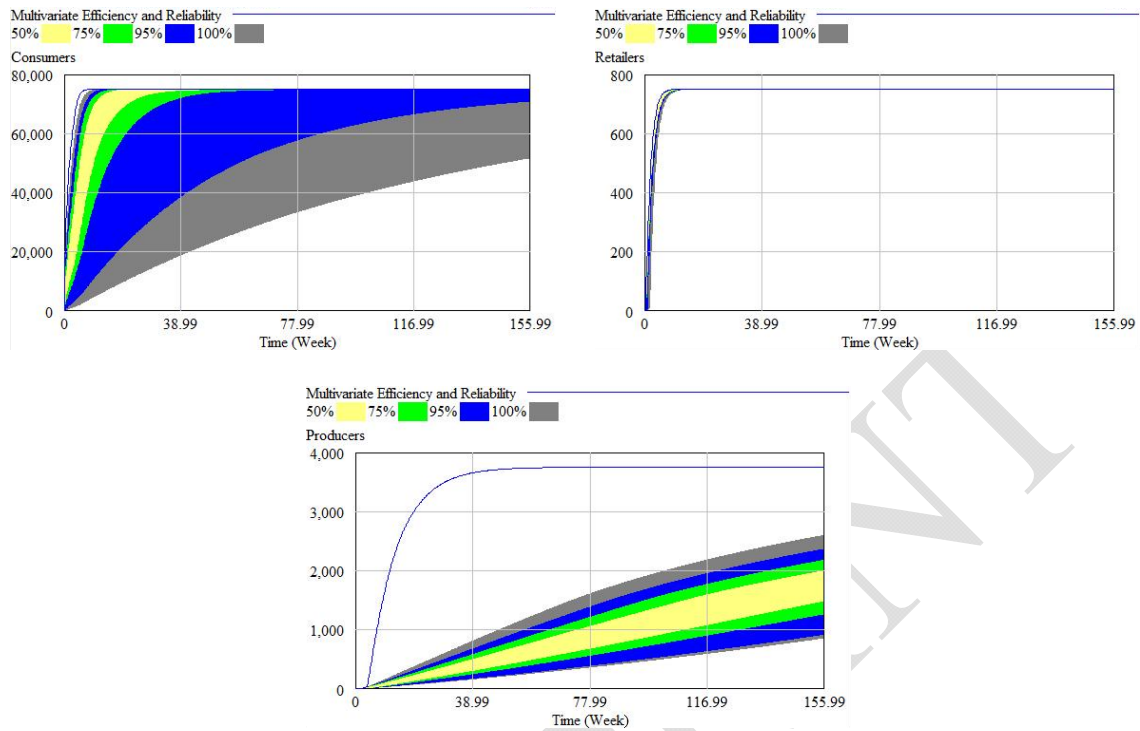


Figure 9. Sensitivity analysis on efficiency/reliability parameters

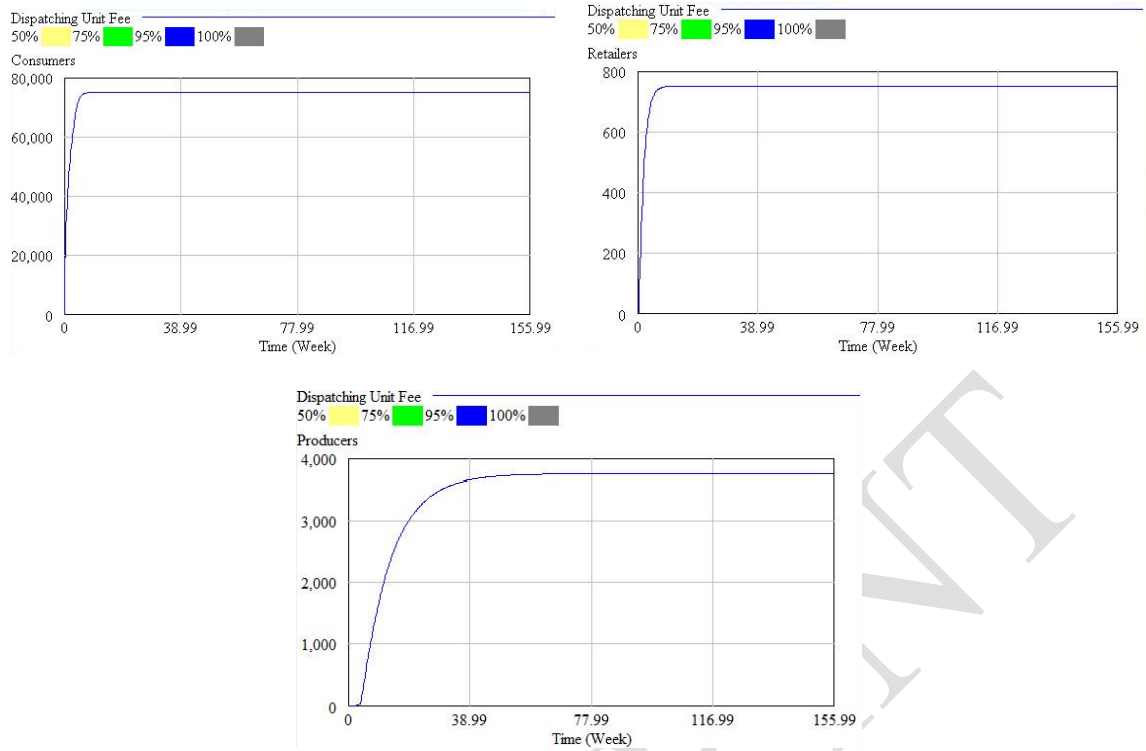


Figure 10. Sensitivity analysis on “Dispatching Unit Fee”

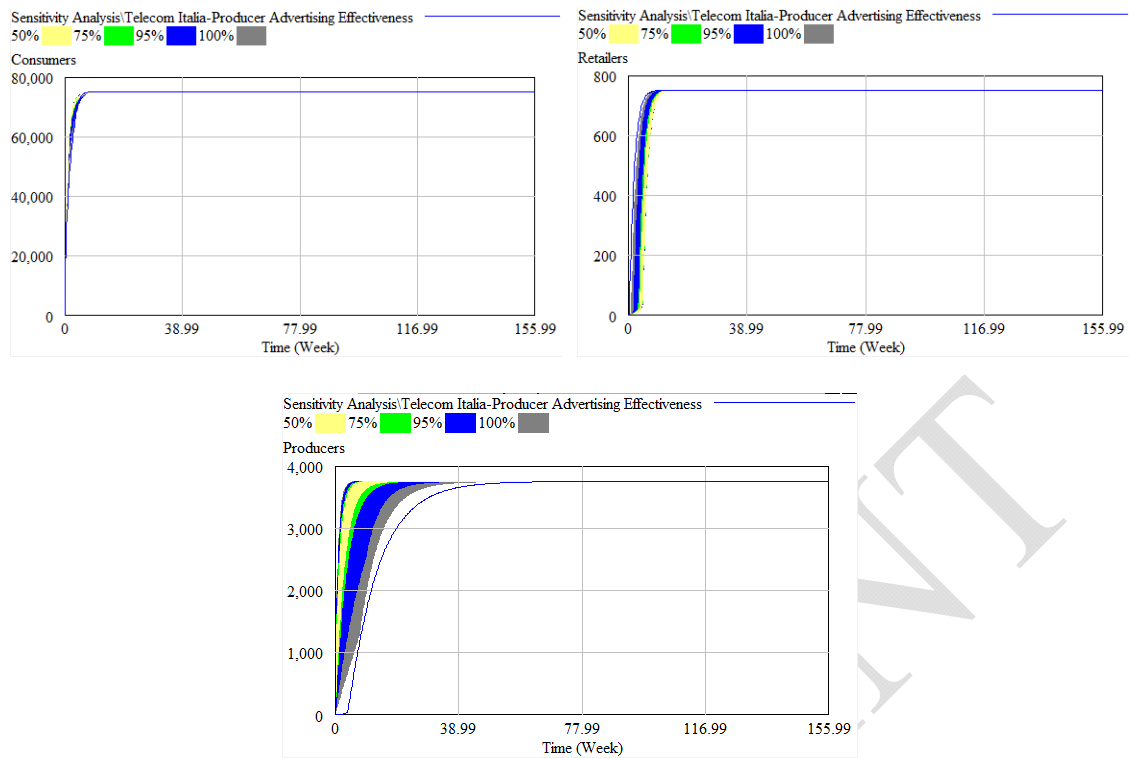


Figure 11. Sensitivity analysis on “Telecom Italia-Producer Advertising Effectiveness”

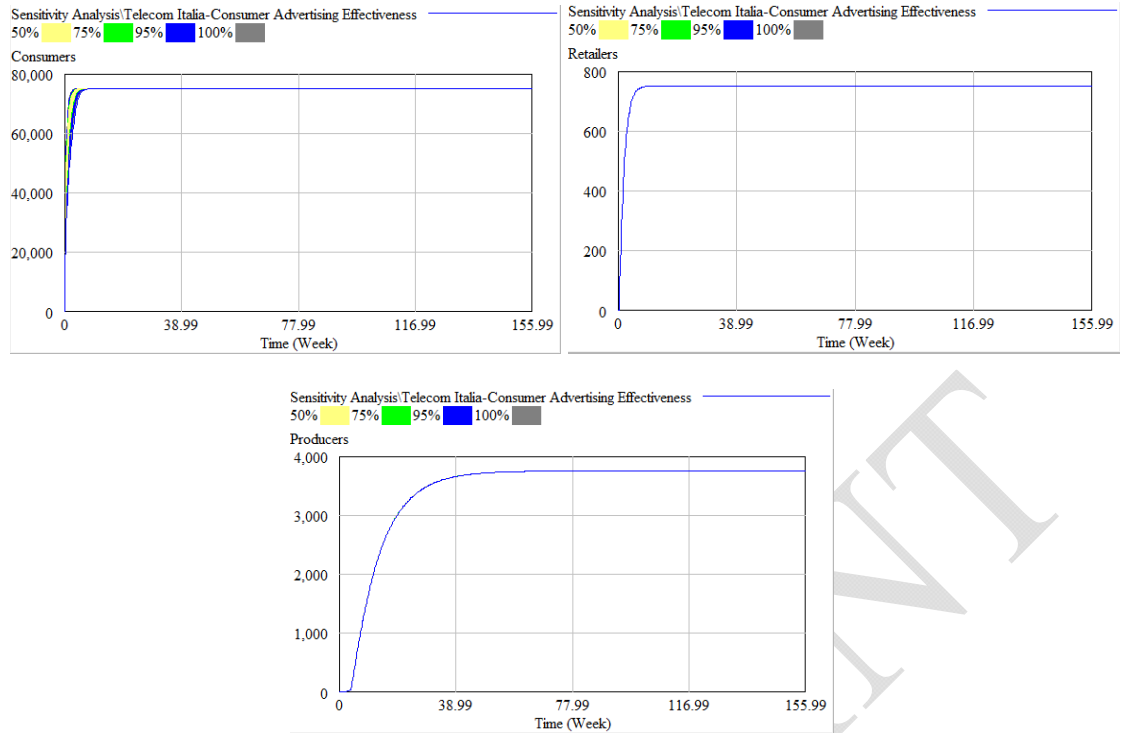


Figure 12. Sensitivity analysis on “Telecom Italia-Consumer Advertising Effectiveness”

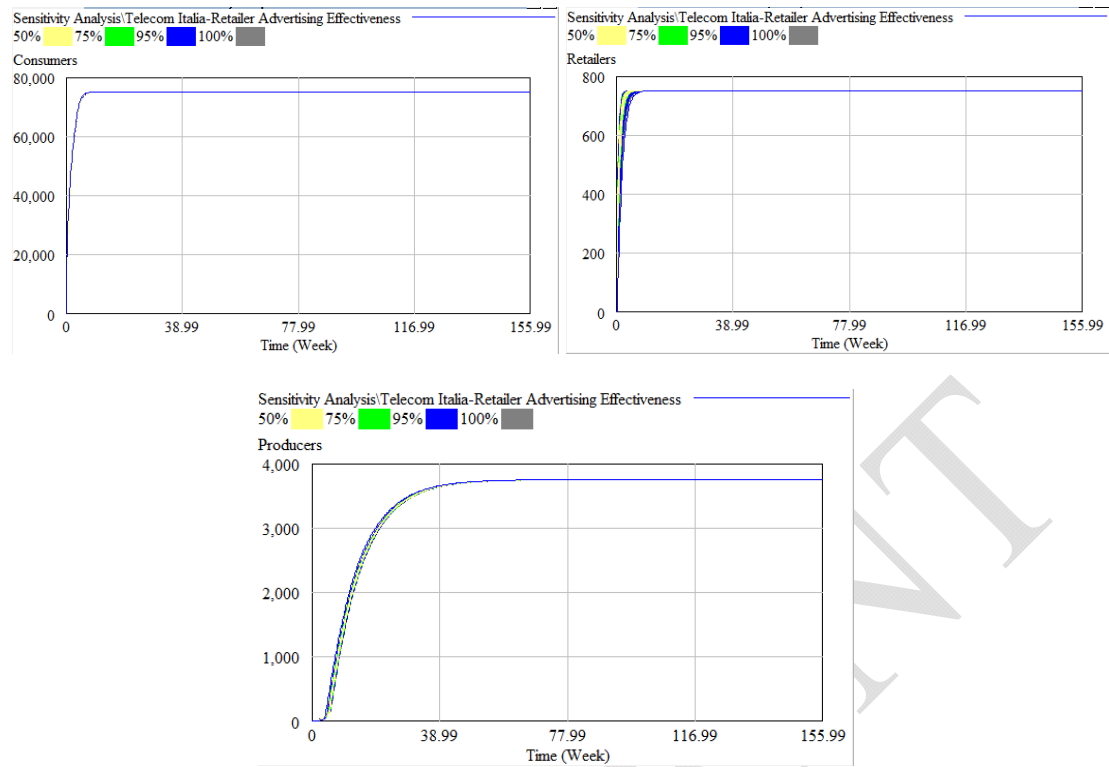


Figure 13. Sensitivity analysis on “Telecom Italia-Retailer Advertising Effectiveness”

Variable	Input value			Unit
	Min value	Set value	Max value	
Total population				
Total Consumer Population		75,000		Users
Total Retailer Population		750		Users
Total Producer Population		3,750		Users
Contact rates				
Consumer Contact Rate	0	0.2	10	1/Time
Retailer-Retailer Contact Rate	0	0.2	10	1/Time
Producer-Producer Contact Rate	0	0.01	10	1/Time
Advertising effectiveness				
Telecom Italia-Consumer Advertising Effectiveness	0	0.001	1	1/Time
Telecom Italia -Retailer Advertising Effectiveness	0	0.001	1	1/Time
Telecom Italia-Producer Advertising Effectiveness	0	0.001	1	1/Time
Orders&inventory				
# Orders/Consumer		0.2		Order/(User*time)
Minimum Retailer Order Processing Time		0.2		Time
Minimum Producer Order Processing Time	0.2	0.6	1	Time
Pricing				
Receiving Unit Fee	0.001	0.01	1	€/Order
Dispatching Unit Fee	0.001	0.03	1	€/Order
WebApp Unit Price	0.001	2	15	€/User

Table 1. Main input data for model calibration

POST PRINT